



PIER Energy-Related Environmental Research

Environmental Impacts of Energy Generation, Distribution and Use

Use of Degraded Water Sources as Cooling Water in Power Plants

Contract #: 100-98-001

Contractor: Electric Power Research Institute (EPRI)

Contract Amount: \$155,974

Contractor Project Manager: Kent Zammit

Commission Project Manager: Joe O'Hagan

Commission Contract Manager: Joe O'Hagan

The Issue

Freshwater is California's most vital and contested resource. From the Klamath River in the north to the New River in the south—and everywhere in between—an adequate supply of this "liquid gold" is necessary to ensure the state's well-being and prosperity. However, fierce competition among agriculture, industry, the environment, and a rapidly growing population are now stressing this resource to its breaking point. Coupled with the pressures that California's extreme flood and drought cycles put on the state's water supply—as well as a forced reduction of supply from the Colorado River—the state faces a shortage of freshwater in the years to come. In fact, the California Department of Water Resources (DWR) predicts that if current trends continue, the state's water demand will exceed supply by 2020.¹ Without a strategic plan for wise water use, many sectors of California could be hard hit when faced with declining water supplies.



Cooling tower operation using reclaimed water

The power industry is one such sector. Thermal power plants—that is, those that use steam to produce electricity—can consume large amounts of water, most of which is used in the cooling process. Depending on the type of cooling tower, the cooling process can account for up to 90%–95% of total plant water use.² Most commonly, these plants use evaporative cooling towers, which draw significant quantities of water. Large 500- to 1,000-megawatt combustion-

¹ California Department of Water Resources. 1998. "The California Water Plan Update Bulletin 160-98." <http://rubicon.water.ca.gov/pdfs/es/esch1.pdf>.

² Maulbetsch, John S. 2002. *Comparison of Alternate Cooling Technologies for California Power Plants*. California Energy Commission. [Publication # 500-02-079F](#).

turbine, combined-cycle facilities with closed-loop cooling may use 3.5 to 5 million gallons per day.³

In California (and throughout the world), competing demands for freshwater, along with environmental, health, and safety concerns and aesthetic issues, have forced thermal power plant operators to consider alternative cooling water supplies, such as degraded or reclaimed water sources. Degraded water is surface water, groundwater, treated municipal effluent, or industrial process water/wastewater that is not suitable for drinking because it contains natural or human-made contamination. Reclaimed water refers to treated wastewater from a wastewater treatment plant or water that has been used in another industrial process. Its reuse allows surface or groundwater to be used by water-demanding sectors that must use freshwater.

Both regulations and a voluntary agreement call for the use of degraded and reclaimed water. California Water Code Section 13550 requires the use of effluent water for industrial purposes (especially for cooling) in many instances, if it is available. And in 1994, federal, state, and private organizations⁴ adopted a Statement of Support for Water Reclamation.⁵ This statement supports the pursuit and development of federal, state, and local policies and regulations that will reduce constraints on the use of degraded and reclaimed water and promote water reclamation.

However, the use of degraded and reclaimed water remains limited. For power plant operators to increase their use of degraded and reclaimed water, they must understand the economics and operational and environmental impacts of using it. Better knowledge of these factors, coupled with the ability to identify appropriate degraded or reclaimed cooling water sources, will enable electricity producers to expand their use of alternative water sources and reduce the demand on local freshwater supplies.

The Energy Commission estimates that if all of the power plants currently projected to be built in California in the next five years used degraded water for cooling, approximately 118,000 acre-feet per year of freshwater could be diverted to other uses.⁶

Project Description

In this project, PIEREA and EPRI reviewed the relative costs and environmental impacts of using untreated, degraded, or reclaimed water. Researchers sought to (1) identify potential types of degraded water, the pollutants specific to these types of water, and the water quality requirements necessary for cooling water; (2) investigate the technical and economic feasibility of using degraded or reclaimed water for power plant cooling; and (3) identify commercial and emerging treatment technologies to treat degraded or reclaimed water.

The project developed a six-step Source Water Evaluation Methodology to help power producers assess degraded and freshwater sources for cooling tower makeup: (1) identify and characterize the source water; (2) evaluate constituents of concern, including PO₄, Cu, Al, S, NH₃, biological

³ California Energy Commission. July 2001. *Environmental Performance Report of California's Electric Generation Facilities*. [Publication # 700-01-001](#). p. 28.

⁴ The U.S. Environmental Protection Agency (Region 9), the California Water Resources Control Board, the California Department of Water Resources, the California Department of Health Services, the California Conference of Directors of Environmental Health, the U.S. Bureau of Reclamation, and the WateReuse Association.

⁵ WateReuse Association. <http://www.watereuse.org/>.

⁶ This calculation is based on information from the California Energy Commission website, www.energy.ca.gov/sitingcases/status_all_projects.html.

oxygen demand, and chemical oxygen demand; (3) identify cooling tower design and operating impacts; (4) determine the need for treatment; (5) determine specific treatment requirements; (6) evaluate disposal issues. The methodology focuses on minimizing cooling tower operation and maintenance problems such as loss of heat transfer, fouling, and corrosion.

Using this methodology, the research team developed hypothetical case studies for three different types of degraded water used for power plant cooling: (1) saline process wastewater generated by oil production in the Central Valley, (2) saline water generated by flood irrigation of crops in the Central Valley, and (3) reclaimed (treated) municipal effluent in the San Francisco Bay Area. For each scenario, researchers considered operating data, treatment equipment requirements, chemical and power consumption, sludge production, and dedicated labor and operating and capital costs. These costs were benchmarked against freshwater cooling scenarios to ascertain the technical and economic feasibility of using degraded water sources in cooling towers.

The project also assessed the environmental, health, and safety impacts of all streams leaving the cooling system—including cooling tower blowdown, drift, water loss to evaporation (including evaporated chemical constituents), waste streams from treatment of the cooling circuit, and sludge from cooling tower maintenance.

In addition, this research identified commercial and emerging technologies for treating degraded water sources.

PIER Program Objectives and Anticipated Benefits for California

This project offers numerous benefits and meets the following PIER program objectives:

- **Providing safe and environmentally sound electricity.** This work provides a basis for power producers to decrease the amount of freshwater needed for power plant cooling. As a result, approximately 118,000 acre-feet per year (105 million gallons per day) of fresh surface or groundwater could be diverted to other uses. Environmental health is improved by limiting the amount of water that must be diverted from natural habitats and the ground. The project promotes public health and worker safety by identifying the potential impacts of using degraded water sources, as well as responsive mitigation strategies. This research also identifies promising treatment processes that could benefit aquatic habitats.
- **Providing reliable and affordable electricity.** Greater use of degraded and reclaimed water will allow power plants to be built closer to end users—without compromising community water supplies. Consumers could save even more by delaying or eliminating the need to expand potable water supply and treatment facilities.⁷

Results

Alternative water supplies offer significant opportunities for power plants to limit their use of freshwater. Potential sources of degraded water include contaminated groundwater, treated municipal effluent, industrial process water or wastewater, irrigation return water, brackish water, and other types of water impacted by humans or naturally occurring minerals.

⁷ U.S. Environmental Protection Agency. 1992. “How to Conserve Water and Use It Effectively.” www.epa.gov/water/you/chap3.html.

Degraded water requires treatment to be appropriate for power plant cooling. *Pre-treatment* is typically necessary to render degraded water environmentally safe and chemically appropriate for cooling tower operations. Pre-treatment can remove contaminants, adjust pH, soften the water (remove calcium and magnesium), and reduce silica or total suspended solids (TSS). *Sidestream treatment*—treating a portion of the recirculating water—can soften, reduce silica, and reduce TSS, thereby preventing fouling/scaling and increasing the cycles of concentration. *Post-treatment* can reduce blowdown discharge volume or meet environmental discharge requirements.

The final report discusses commercial processes for treating degraded water, including air stripping, liquid-phase granular activated carbon, aerobic and anaerobic biological treatments, strong-base anion exchange, chelating ion exchange, and precipitation methods.

The project also identified emerging treatment technologies that show promise: (1) an anion liquid ion exchange process to remove chromium (+6) without generating large amounts of sludge; (2) selective electrochemically regenerated ion extraction to remove arsenic and chromium; (3) imprinted ferrihydrite sorbents that selectively remove heavy metals without generating sludge; (4) genetically engineered E-coli bacteria that sequester heavy metals; (5) a passive process using zeolite to decompose pesticides without generating a liquid or solid waste stream; (6) a natural enzyme (phosphotriesterase) to detoxify organophosphate pesticides without generating a liquid or solid waste stream; (7) modified polydimethylsiloxane (PDMS) membranes to remove polar organic compounds; (8) biofilter removal of volatile organic compounds (VOC) from airborne emissions; (9) hypercrosslinked polymer matrices to adsorb organic compounds; and (10) carbon aerogels to remove perchlorate and inorganic salts.

Case study results showed that the costs of using degraded water are at least 1.5 to 2.5 times the costs associated with freshwater at inland plants and 1.1 to 1.2 times that of freshwater at coastal plants (naturally, these ranges vary with the quality of the water source).

Occupational safety and environmental issues associated with degraded water include exposure to bacteria such as *Legionella pneumophila*; chemicals in untreated degraded water, such as volatile compounds, pesticides, heavy metals, hydrogen sulfides, and other hazards; biological control chemicals such as chlorine and bromine compounds; specialty chemicals used to scale and corrosion control; water treatment chemicals and waste streams such as sulfuric acid, sodium hydroxide, and hydrated lime; and maintenance wastes such as biological sediments.

Final Report

The final report on the results of this work, *Use of Degraded Water Sources as Cooling Water in Power Plants* (CEC-500-03-110), is posted on the Energy Commission website at http://www.energy.ca.gov/reports/2004-02-23_500-03-110.PDF.

Contact

Joe O'Hagan • 916-653-1651 • johagan@energy.state.ca.us